An-AUV Based Investigation of the Role of Nutrient Variability in the Predictive Modeling of Physical Processes in the Littoral Ocean

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Award #: N00014-96-1-5024
http://www.marine.usf.edu

LONG-TERM GOAL

Our long-term goal is to assess the effectiveness of nutrients as tracers of geophysical fields in the oligotrophic littoral ocean, utilizing various sampling and measurement protocols in a feedback approach with a prognostic physical/biogeochemical model. Ultimately, relevant nutrient gradients are to be measured by a nutrient sensor aboard an AUV.

OBJECTIVES

Our more immediate and specific objectives fell into two groups: (1) those associated with the decision about and the initial development of a prognostic model suitable for coastal waters on the West Florida Shelf and (2) those associated with the high-sensitivity nutrient methods used to map nutrient distributions and gradients on the West Florida Shelf in support of the modeling effort. Group (2) objectives included improvement of our analytical methods for nitrate, nitrite, and ammonia; investigation of a high-sensitivity phosphate method; and preliminary field studies of spatial scales of the nutrient distributions that would eventually be the subjects of both nowcasting and predictive modeling.

APPROACH

Because of a coalescence of multi-investigator interest in a region of the West Florida Shelf now called the Control Volume between the 10-m and 50-m isobaths from Tampa Bay south to Charlotte Harbor (see Fig. 1 and below), we focused most of our modeling and field efforts there. The region is now bounded by ADCP arrays maintained by Bob Weisberg and Mark Luther of USF and also contains additional interior ADCP arrays with moored optical sensors: hyperspectral radiometers, backscatterometers (660 and 880 nm), c-meters (288 and 660 nm), and fluorometers (chlorophyll and CDOM) deployed by Ken Carder of USF.

However, we began the model development by examining both SF_6 studies and high-sensitivity nutrient measurements from the Florida Shelf Lagrangian Experiment (FSLE) region just to the north.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **1998**	2. REPORT TYPE	3. DATES COVERED **00-00-1998 to 00-00-1998**

4. TITLE AND SUBTITLE **An-AUV Based Investigation of the Role of Nutrient Variability in the Predictive Modeling of Physical Processes in the Littoral Ocean**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of South Florida,Department of Marine Science,St. Petersburg,FL,33701-5016**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002252.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Next, we assembled nutrient, optical, and plankton information from 1998, 1979, 1965-67, and 1958-61 as validation data for the coupled biochemical/physical models we will generate for littoral ocean processes in the Control Volume.

Improvements to nutrient techniques and sensors focused specifically on those designed for AUV deployment.

We conducted field studies to test methods for nutrient gradient determination and to provide initial estimates of the size and distribution of nutrient patches that might serve as circulation tracers.

WORK COMPLETED

In the FSLE study of April 1996, SF_6 distributions provided an estimate of eddy mixing on the West Florida Shelf (Wanninkhof et al., 1997), and high-sensitivity nanomolar levels of nitrate, nitrite, and ammonia showed spatial gradients not observed in temperature and salinity fields. Therefore, in the past year we used comparisons of nanomolar nutrient levels from the first and second halves of FSLE to obtain a preliminary estimate of the size and movement of nutrient patches on the West Florida Shelf. Then we examined a barotropic simulation of the FSLE SF_6 dispersion with Lagrangian drifters using the Princeton Ocean Model (POM) to determine whether or not a purely POM-based modeling approach had sufficient resolution.

Archived data on pigments and nutrients from in and near the Control Volume taken by the Florida Dept. of Environ. Protection (FDEP, formerly the Florida Dept. of Natural Resources or FDNR), from Coastal Zone Color Scanner (CZCS) imagery, and by the US Fish and Wildlife Service (USFWS) were examined for clues about patch sizes of biogeochemical variables that might provide bounds on the spatial scales appropriate for prognostic modeling.

Upgrades on nutrient methods included improvements in electronics, design and testing of pressure housings, completion of chemical heat exchangers, and modifications in chemical and optical conditions of the analyte-reagent reactions to increase sensitivity.

Finally, during 22-23 September 1998 and in collaboration with Tom Hopkins of USF, we conducted a high-resolution, cross-shelf section of the nutrient (Fig 2), hydrographic (Fig. 2), optical, and plankton fields past the moored arrays within the Control Volume (Fig. 1). This was our first field test in the coastal region to which both nowcasts and model prognostications will be applied.

RESULTS

From the first FSLE-related study (nutrient distributions), we learned that the proximate size and motion of discrete boluses of water with different nutrient signatures on the West Florida Shelf could only be followed with samples taken $\leq$ 5 nautical miles apart in regions of no more than 25 square nautical miles over periods of 3-5 days. Less frequent or less closely spaced sampling results in aliasing. In the

second FSLE-related study (POM-based simulation of SF_6 and drifters), a preliminary numerical assessment of the utility of embedding a series of circulation models for both the whole West Florida shelf and smaller regions (e.g. the Control Volume) was made; Huijun Yang of USF used the Princeton Ocean Model (POM) at 9-km grid spacing to simulate both the measured dispersion of SF_6 during FSLE and drifters (data from T. Sturges of Florida State University). While the general tracks of the chemical tracer and drogues were correctly approximated by POM, our conclusion was that a non-hydrostatic, large-eddy simulation (LES) circulation model must be nested within POM to correctly describe the physical habitat of biochemical and bio-optical variables on the West Florida shelf. This finding dictated a major shift in our prognostic modeling of nutrient gradients on the West Florida Shelf. R. Garwood of the Naval Postgraduate School is now collaborating with us to provide LES modeling.

We found archived data relating to spatial scales of patches of surface waters in and near the Control Volume. During a red-tide study of *G. breve* in November-December 1979 by Ken Haddad of FDEP (Fig. 1), the red-tide biomass was ~ 10 µg chl l^{-1} at one station above the 25-m isobath during 5-6

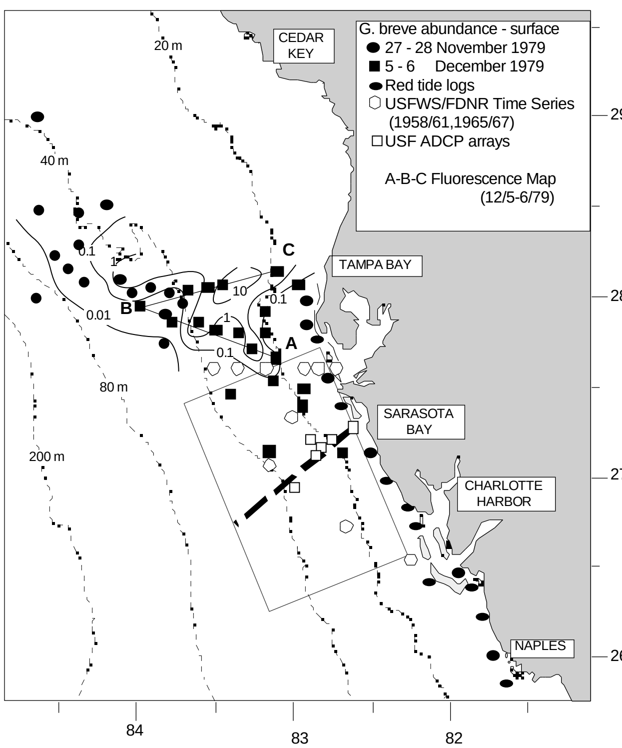


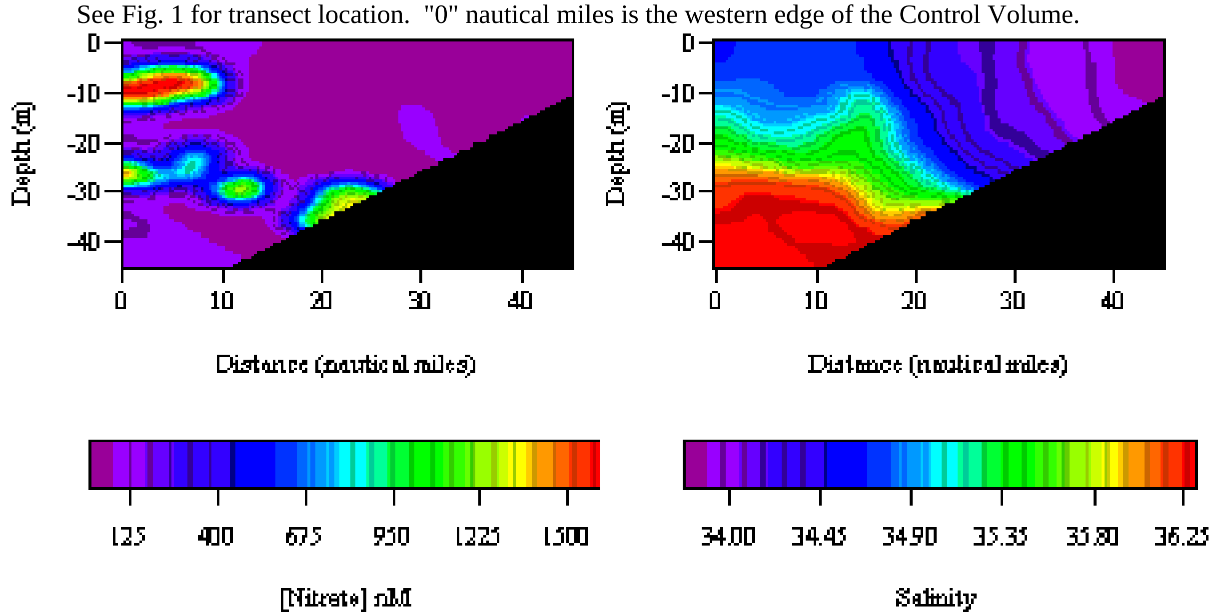
Fig. 1. A cross-shelf section of nutrient, hydrographic, and plankton fields through the Control Volume past the USF moored arrays (heavy dashed line). Shown also are FDEP/FDNR surface observations of G. breve abundance (10^5 cells l^{-1}), FDEP red tide plankton logs on piers and bridges, and time series for FDEP (1965-67) and USFWS (1958-61).

November 1979, if we assume that 1 µg chl l^{-1} ≈1 x 10^5 *G. breve* cells l^{-1}. The concurrent underway fluorescence map (A-B-C) suggests that the feature indeed had a biomass of >2 µg chl l^{-1} over a ~10-km width during this cruise. Furthermore, concurrent CZCS data exhumed by Frank Muller-Karger of USF indicates an ~10-km band of high apparent pigments (>2 µg chl l^{-1}) extending south along this isobath from ~28^{o}30'N to ~27^{o}30'N during 16, 27 November 1979 and 12 December 1979 - mirabile visu! This indicates that the surface features to be modeled are frequently ~10 km wide along fronts. To test additional hindcasts of our models, we have uncovered, but not yet fully interpreted, 34-months of information from past USFWS and FDEP/FDNR surveys of *G. breve* cell counts, Secchi depth estimates of k_d, temperature, salinity, NO_3, PO_4 and SiO_4 (Fig. 1).

Our upgrade of the performance of the *in situ* nutrient sensor for nitrate, nitrite, and ammonia for an AUV included the following: (1) Design, manufacture, and pressure testing of housings for various components within the nutrient sensor; (2) Design, manufacture, and population of circuit boards for the sensor; (3) Assembly and debugging of electronics in pressure housings; (4) Redesign of the optical system to increase the fluorescent signal of the analyte and achieve 10 nM sensitivity in rectangular flowcells; (5) 95% completion of the AUV nose cone which will house the nutrient sensor; (6) Manufacture, assembly, debugging, and testing of chemical heat exchangers: (7) 95% completion of the Graphical User Interface (GUI); (8) Determination that salinity has no effect on analytical reactions involving nitrate and nitrite; and (9) Finalization of *in situ* nutrient sensor design. An attempt to utilize rectangular flow cells at 30 atm pressure was unsuccessful, but “supersil” cylindrical flowcells will work at 30 atm pressure. However analytical sensitivity in cylindrical flowcells is only 30 nM. Work continues on attempting to shift cylindrical-flowcell sensitivity closer to 10 nM. Because reagents for a fluorescent phosphate technique will be too expensive, the search for a viable high-sensitivity phosphate technique continues.

During the 2-day transect through the Control Volume (see above and Fig. 1), we determined surface nanomolar nutrient concentrations (NO_3, NO_2, NH_3) by regular, continuous sampling of a stream of seawater from an intake port at 2 meters depth and deeper nutrient distributions by using collection bottles on the High-Resolution Plankton Sampler of Tom Hopkins during oblique tows. Combined results (Fig. 2) have several interesting features. High nitrate markers sometimes denote the same water type as salinity and sometimes do not. A series of higher nitrate boluses appear to emerge from the bottom at 22 nautical miles and then follow the 35.9 salinity contour back toward 0 nautical miles. However a second, high-nitrate bolus located 10 meters deep between 0 and 10 nautical miles is found

Fig. 2 Nitrate and Salinity Cross Sections along the transect run across the Control Volume in September, 1998. See Fig. 1 for transect location. "0" nautical miles is the western edge of the Control Volume.



in fresher water over salinities of 34.8-35.0 and seems unconnected to the deeper series. Further, water in that salinity range continues in toward shore, eventually contacting the bottom at 27 nautical miles while the high-nitrate lens stops at 11 nautical miles. Thus we obtained an excellent example of the

“different” picture of circulation that nutrients can supply. We also have preliminary estimates of the scales of nutrient lenses that might be expected in coastal waters. Fig. 2 indicates that, below the surface, lenses can be 5-10 m thick and 4-10 nautical miles wide with nitrate concentration ranges of 500-1400 nanomolar. Our surface data on intake-port water (not shown) indicate that surficial nutrient lenses can be 5-15 nautical miles wide with concentration ranges of ~35 nanomolar.

IMPACT/APPLICATION

The validated models will be used to predict and interpret surface and subsurface chemical signals detected by AUVs and surface optical signals sensed by the Coastal Ocean Imaging Spectrometer (COIS) instrument aboard the Navy Earth Map Observer (NEMO) satellite in coastal waters.

TRANSITIONS

The models will also be used to predict red tides as part of the EPA/NOAA ECOHAB studies along the West Florida shelf.

RELATED PROJECTS

1 – R. Wanninkhof of AOML/NOAA studies SF_6 studies of gas exchange and turbulence in coastal waters. He will be part of the next phase of our analytical/modeling work on the Control Volume

2 – T. Hopkins of USF is funded by ONR to develop a plankton sampler that also distinguishes particles, pigments, and light penetration. The collaboration shown in Fig. 2 will be extended.

3 - Several investigators here at USF (R.Weisberg, J.Walsh, K.Carder, G.Vargo) are funded to study red tides (ECOHAB project) and the prediction of optical signals to satellites (HyCODE). All of this research is centered on the Control Volume and will utilize the data and models we generate.

REFERENCES

Wanninkhof, R., Hitchcock, G., Wiseman, W., Vargo, G., Ortner, P., Asher, W., Ho, D., Schlosser, P., Dickson, M., Masserini, R,. Fanning, K., and Zhang, J.-Z. 1997: Gas exchange, dispersion, and biological productivity on the west Florida shelf: results from a Lagrangian tracer study. Geophys. Res. Lett., 24, 1767-1770.

PATENTS

Method for Measuring Nitrite and Nitrate in Aqueous Medium. Verbal approval of patent received September 1998. Serial number 08/915,704. Issue fee paid. Awaiting final U.S. patent number.